# OPERATING AND MAINTENANCE MANUAL

# DIGITAL CURRENT METER MODEL 1776

F.W. BELL

F.W. Bell Digital Current Meter
Instruction Manual

360670

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## SIMPLIFIED OPERATING INSTRUCTIONS

1. Connect the 1776 Digital Current Meter to the appropriate power source. Connect the probe to the 1776. Turn the instrument on. A warm-up time of ½-hour is recommended.

2. Depress the CAL button and adjust the calibration potentiometer to obtain a 1000 reading. The instrument is now calibrated. Release the CAL button.

3. With the probe connected, but not clamped around an unknown current, adjust the COARSE and FINE zero controls to obtain a zero meter reading. The instrument is now ready to make measurements.

4. To make ac measurements, depress the ac/dc button. For dc measurements, the button should be in the released position. To make the measurement, simply clamp the probe around the unknown current and read the meter. Remember that the dc mode measures the dc component of the unknown current. The ac mode measures the ac component of the unknown current. The meter is average responding, calibrated to indicate the rms value of a pure sine wave function.

5. The PEAK reading button is used to read and hold the peak current present during a particular time span. Depress the PEAK button. The meter will display the highest *positive* peak current which flows through the conductor during the time the button is depressed. If there is more than one peak, the instrument will display the maximum absolute peak current. The reset clears the hold circuitry and prepares it for reading a new peak.

*Please read this entire manual for complete instructions.*

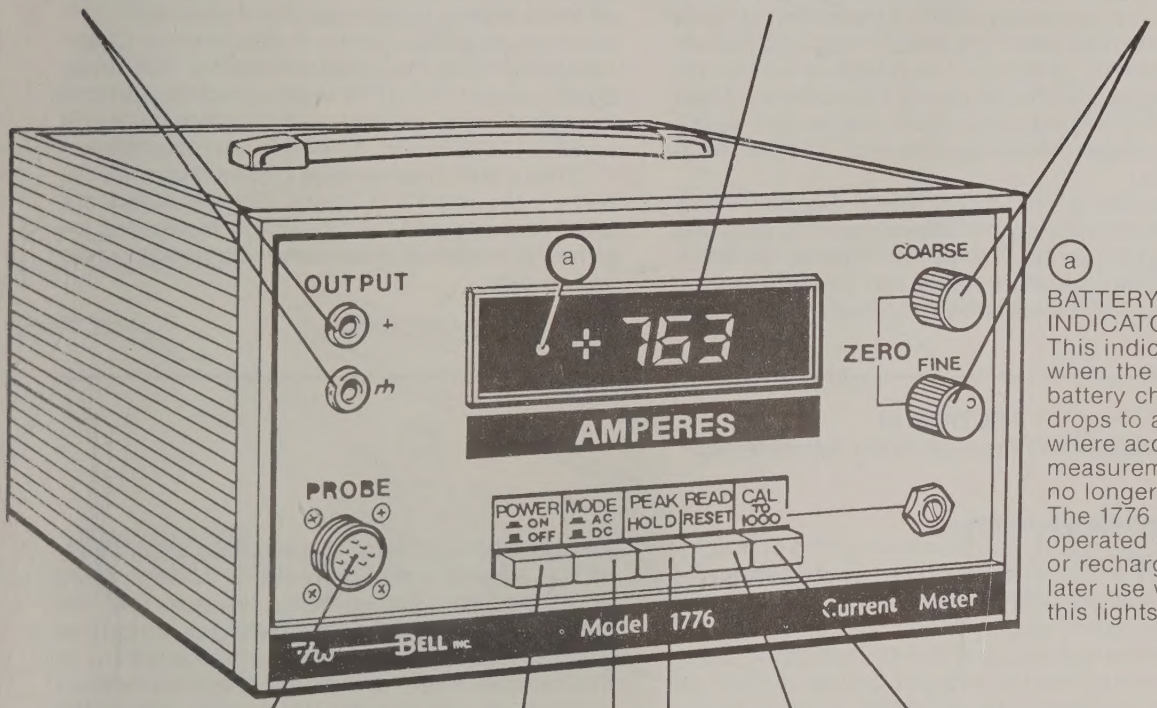
## SPECIFICATIONS

| | |
|---|---|
| **CURRENT RANGES, dc and ac rms** | 0 to 10.00 A FS with probe P-100; overrange to 19.99 A.<br>0 to 100.0 A FS with probe P-101; overrange to 199.9 A.<br>0 to 1000 A FS with probe P-102; no overrange. |
| **OVERALL ACCURACY, INCLUDING PROBES**<br>**dc and sinusoidal ac to 1000 Hz** | normal range: ±1.0% FS at 25°C.<br>overrange: ±2.5% FS at 25°C. |
| **peak reading** | ±2.0% FS. |
| **FREQUENCY RESPONSE IN ac MODE**<br>**additional error 1000 Hz to 5000 Hz** | 10 Hz to 5000 Hz.<br>with P-100 (10 A) probe: +2.0% of reading, typical.<br>with P-101 (100 A) probe: +3.0% of reading, typical.<br>with P-102 (1000 A) probe: +3.0% of reading, typical. |
| **PEAK READING** | frequency response: 1000 Hz.<br>fastest readable rise time: 250μs to full scale. |
| **OUTPUT VOLTAGE** | in dc mode: ±1.0V for full scale indication. in ac mode: 1.0 V rms for full scale indication of sinusoidal current.<br>in peak hold mode: +1.0 V hold for full scale peak hold indication. |
| **READOUT** | digital, 3½ digits. |
| **PROBE ISOLATION CAPABILITY** | 600 V dc or ac peak. |
| **POWER REQUIREMENTS** | 115/230 V ac, 50/60 Hz and internal rechargeable Nicad batteries with built-in trickle charge circuitry (voltage selection is made at the factory) 15 W. |
| **SIZE** | 5½" high, 10" wide, 10" deep (140 mm x 254 mm x 254 mm). |
| **WEIGHT** | net 10 lbs. (4.5 kg), shipping 13 lbs. (5.9 kg) |
| **OPERATING TEMPERATURE RANGE** | −10°C to +50°C. |
| **SPECIAL FEATURES** | All probes can be calibrated using the internal calibration feature of any 1776. The P-100 (10A) and P-101 (100A) probes have 100% overrange capability with slightly reduced accuracy. |

OUTPUT
±1 volt for full scale indication on dc, 1 volt rms for full scale indication on ac.

DIGITAL READOUT
This 3½ digit display shows the current measured. Polarity of dc currents is also indicated.

ZERO
*Coarse* and *fine* zero controls, zero the instrument reading.




(a) BATTERY INDICATOR
This indicator lights when the internal battery charge level drops to a point where accurate measurements are no longer possible. The 1776 should be operated on the line or recharged for later use when this lights.

PROBE CONNECTOR
One of three available probes can be connected here. The instrument automatically ranges to the appropriate probe when it is connected.

ON/OFF SWITCH
Depress this button to turn the instrument on.

CALIBRATE
Depress this button to calibrate the 1776 to a full scale reading of 1000.

AC-DC FUNCTION
When depressed, this switch permits ac current measurements. When released, the instrument is in dc mode.

RESET
This button clears the peak reading indication and prepares the instrument for the next peak reading.

PEAK READ
When the HOLD button is depressed, the 1776 will read and hold the highest positive peak current indefinitely until the RESET button is used to clear the instrument.

## DESCRIPTION

The Bell model 1776 Digital Current Meter provides a revolution in metrology via its ability to accurately measure ac, dc, (and ac on dc) current with a non-contact clamp-on probe. No longer is it necessary to break the circuit to make a current measurement. This time saving feature is extremely helpful in the troubleshooting, repair, and design fields. Now it's possible to obtain current measurements more easily and safely than voltage measurements with isolation from the bus.

The Bell model 1776 Digital Current Meter introduces virtually no resistance on dc readings and extremely small impedance on ac readings. In this way, measurements can be made with a minimum of disturbance in the measured circuit, a tremendous advantage in making those difficult transient response tests.

The unique circuit design coupled with the digital readout provides a wide dynamic range of measurements with excellent resolution. For example, readings can be made down to 10 milliamperes while the upper end limit is 1000 amps dc or rms ac.* The 1776 is designed for portable operation with internal rechargeable batteries and for 115/230 Vac, 50-60 Hz line operation.

These and other unique capabilities and features make the 1776 Digital Current Meter the most versatile and useful current measuring instrument available. It has been designed to meet your needs.

*A dynamic range of 100,000 to 1.

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## SECTION III
## Installation and Pre-Operation Adjustments

### III-1
### (a) Power Requirements

The Model 1776 operates from a 115 volt ac or 230 volt ac line at 50 or 60 Hz. Each instrument is pre-adjusted at the factory to the 115 or 230 volt operation levels. Check the rating of your instrument to make sure that the voltages match. Instruments rated at 115 volt operation have no identifying power tag while the 230 volt operation instruments have a tag identifying them as 230 volts. All units accept 50 or 60 Hz power.

Internal rechargeable NICAD batteries provide true portable operation. A built-in trickle charger maintains the NICAD batteries at full charge while the instrument is attached to the ac line and is "on". When attached to the line and "off", the instrument recharges the batteries at a full recharge. For example, after eight hours of portable operation the 1776 should be attached to the ac line in the "off" position for sixteen hours. The instrument draws 15 watts of power.

### (b) Pre-Operation:

Attach the probe connector to the front panel. Make sure the clamp ring is screwed down firmly. Turn the power switch on. For best performance, allow 30 minutes of warm-up before making measurements or calibrating the instrument.

### III-2 CALIBRATION PROCEDURE
### (a) General:

The calibration procedure should be performed before the instrument is used for current measurements. It should also be performed whenever probes are changed. Allow sufficient time for warm-up stability before calibrating.

### (b) Calibration Against Internal CAL Signal:

Calibration against the internal CAL signal is a simple process which normally will provide the best possible accuracy. The accuracy and stability of the internal calibration signal is dependent upon precision high-stability resistors and the initial factory calibration. Therefore, long-term accuracy and high stability is a characteristic of this method. After the instrument and probe have warmed up, depress the CAL button. Adjust the CAL screwdriver adjustment to obtain a 1000 digital meter reading. The instrument is now calibrated. Release the CAL button before zeroing the meter.

### III-3 Probe and Instrument Zeroing:

(a) After calibration, the probe and instrument should be zeroed. Allow the probe to be closed with no current flow through the aperture. This is best achieved by having the probe aperture free of any conductors. Adjust the COARSE then FINE zero controls on the front panel of the 1776 to achieve a zero meter indication. The instrument is now prepared to make measurements.

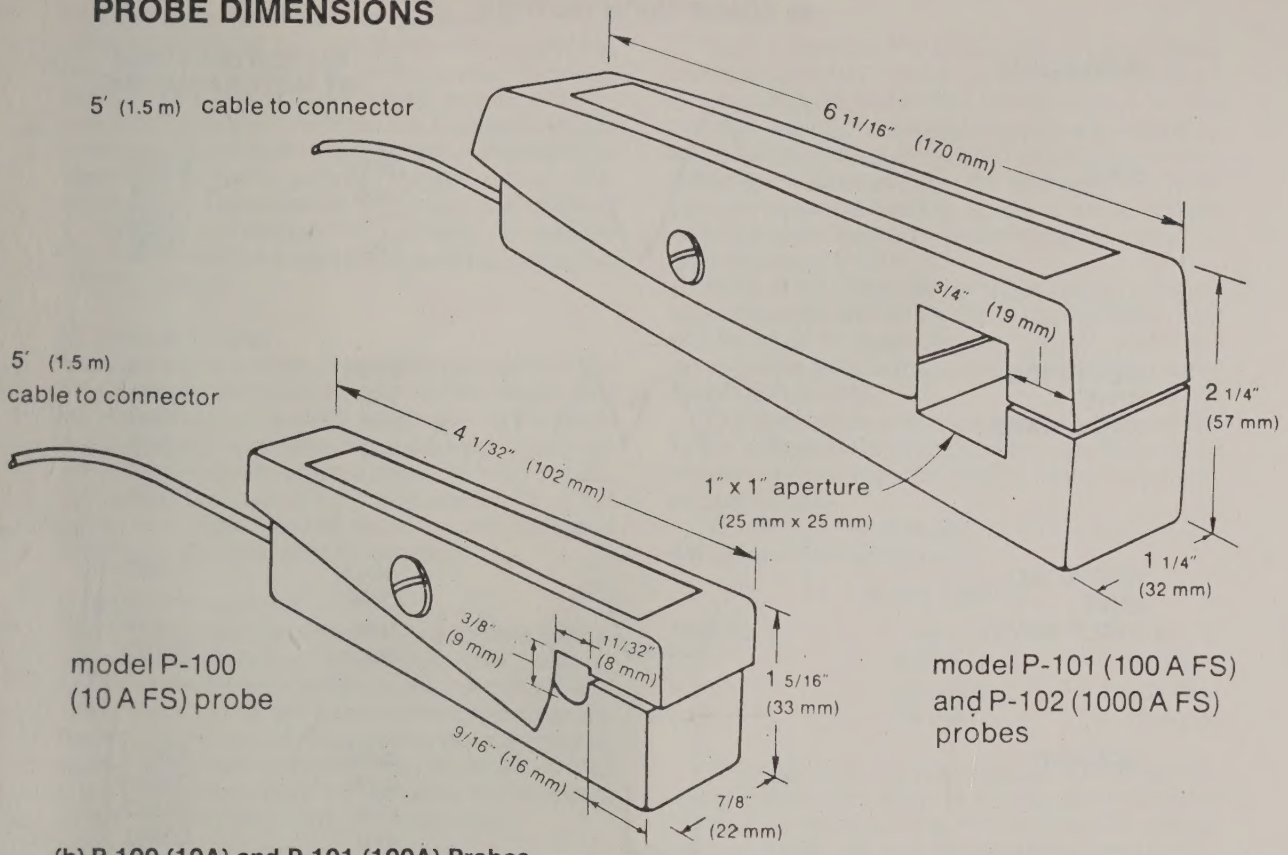
## SECTION IV
## Operating Instructions

### IV-1 Probes
### (a) General:

There are three basic probes for the model 1776 Digital Current Meter. These are clamp-on handheld probes designed to be opened and clamped around the conductor with one hand. For accurate readings, the probe must close completely around the conductor. The instrument range is set by the model of probe selected. See the chart below.

| model | range, A |
|---|---|
| P-100 | 10.00 |
| P-101 | 100.0 |
| P-102 | 1000.0 |

## PROBE DIMENSIONS


5' (1.5 m) cable to connector
6 11/16" (170 mm)
3/4" (19 mm)
2 1/4" (57 mm)
1" x 1" aperture
(25 mm x 25 mm)
1 1/4" (32 mm)
5' (1.5 m) cable to connector
4 1/32" (102 mm)
3/8" (9 mm)
11/32" (8 mm)
1 5/16" (33 mm)
9/16" (16 mm)
7/8" (22 mm)
model P-100 (10 A FS) probe
model P-101 (100 A FS) and P-102 (1000 A FS) probes

**(b) P-100 (10A) and P-101 (100A) Probes**
The 10 and 100 ampere probes are ruggedly designed to clamp around conductors to provide a current measurement. The probes are sturdy and will withstand heavy use. The 10 and 100 ampere probes are conservatively rated so they may be used for a two-times overrange with a slight reduction in accuracy. The reduction is an additional 1.5% of full scale accuracy. This means that a reading with a 10 ampere probe of 10 amperes has an uncertainty of 1% of full scale which would be .1 ampere. If the probe is used to make a reading of 19.99 amperes, the uncertainty is 2.5% of full scale (full scale equals 10 amperes). This is a total of .25 amperes.

**(c) P-102 (1000A) Probe**
The 1000 ampere probe has been designed to be hand-held and easily used. As a result of weight saving, the probe does not have a two-times overranging capability that the lower current probes possess. Considerable error may be experienced if the probe is used above 1000 amperes. The 1000 ampere probe is also very durable and will stand heavy use.

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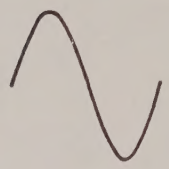
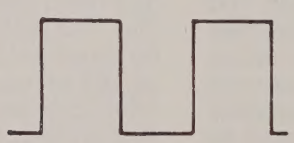
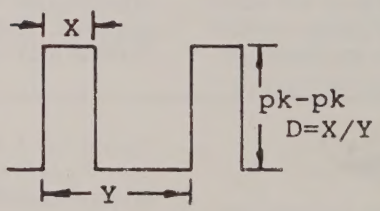
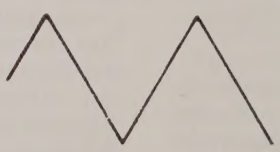
### SECTION IV-2
### Measurement Procedure

**(a) General**
The model 1776 is ready for operation at the conclusion of the pre-operational adjustments.

**(b) dc Measurements**
The ac/dc function switch should be in the dc position. Clamp the probe around the conductor of the unknown current. The current magnitude will appear on the digital panel meter. In addition, a voltage proportional to the current is available at the front panel output terminals. If the current is out of the range of the probe in use (see overrange section), disconnect the probe and connect the appropriate probe for the measurement. Changing probes requires a calibration and zeroing procedure before measurements can be made.

**(c) ac Current Measurement**
Depress the ac/dc function switch. Clamp the probe around the current carrying conductor. The unknown current value will be displayed on the digital readout. This value represents the rms value of the sinusoidal wave shape from 10 Hz to 5kHz. If the measured current is out of the range of the probe in use, change the probe and repeat the pre-operational adjustments. If the measured wave form is not a sinusoid, use the following chart to make the measurements. Multiply the meter reading by the appropriate form factor number. The 1776 is average responding, calibrated to indicate the rms value of a pure sine wave function.

## ac CONVERSION FACTORS

| WAVEFORM | | FACTOR (MULTIPLY BY METER READING) | |
|---|---|---|---|
| SINE |  | pk-pk<br>0-pk<br>rms<br>avg | 2.828<br>1.414<br>1.000<br>0.900 |
| RECTIFIED SINE (FULL WAVE) | | pk-pk<br>0-pk<br>rms<br>avg | 1.414<br>1.414<br>1.000<br>0.900 |
| RECTIFIED SINE (HALF WAVE) | | pk-pk<br>0-pk<br>rms<br>avg | 2.828<br>2.828<br>1.414<br>0.900 |
| SQUARE | | pk-pk<br>0-pk<br>rms<br>avg | 1.800<br>0.900<br>0.900<br>0.900 |
| RECTIFIED SQUARE |  | pk-pk<br>0-pk<br>rms<br>avg | 1.800<br>1.800<br>1.272<br>0.900 |
| RECTANGULAR PULSE |  | pk-pk<br>0-pk<br>rms<br>avg | 0.9/D<br>0.9/D<br>0.9/D½<br>0.9D |
| TRIANGLE AND SAWTOOTH |  | pk-pk<br>0-pk<br>rms<br>avg | 3.600<br>1.800<br>1.038<br>0.900 |

**(d) Peak Read and Hold Measurements**
Clamp the probe around the current-carrying conductor. Depress the peak reading function switch. The front panel digital meter will immediately register and hold the highest *positive* current present from the time the measurement was initiated to the present instant in time. Any subsequent higher peak will cause the reading to increase and hold at the new level. To prepare the instrument for a new peak reading, press the RESET button.

**(e) Voltage Output**
The jacks on the instrument front panel provide a voltage output proportional to the measured current. This can be used for observing the measured current wave form on an oscilloscope or for any other measurement purpose. On the dc scale, the voltage output is a ±1 volt analog for a full scale indication. On the ac scale, the output is 1 volt rms for a full scale indication.

**(f) Battery Operation**
The 1776 is capable of continuous battery operation up to eight hours. When the battery voltage drops below an acceptable level, a warning light will appear at the left side of the meter display. Battery operation at this point is not suggested, as the instrument accuracy may be reduced. Accurate operation may immediately be obtained by connecting the 1776 to the ac line.

The batteries are being charged any time the instrument is on the ac line. If the current meter is in use, the batteries are being trickle-charged to maintain a full charge. When the instrument is in the "off" mode, the batteries are in a maximum charging condition. Two hours of full charging for every one hour of portable operation should maintain the batteries at a fully charged condition.

**(g) Display Overrange**
If the digital current meter is used at a current level greater than *two times* the probe current rating, except for the P-102, 1000 A probe, the digital display will indicate this as an overrange condition. The three least significant digits will blank, leaving the decimal point, a digital "one" and a polarity sign. To obtain a reading at this new level, the probe will have to be exchanged for a probe of the proper rated value.

**(h) Frequency and Current Level Limits**
Clamping a probe for the 1776 Digital Current Meter around a current conductor in which there is a signal which exceeds the ampere•frequency products stated below may be damaging to both the instrument and the probe. This can happen when the 1776 is in either the dc or ac mode of operation.

*Safe Limits on the Use of the Probes:* When the model P-101, 100 A probe is used with the 1776 in the dc mode, the ac component of the current being measured must not exceed an ampere (rms)•frequency product of 1100 A•kHz. When the instrument is in the ac mode, the P-101 probe cannot be used to measure an ac current which has an ampere (rms)•frequency product greater than 750 A•kHz.

With the 1776 in either the ac or dc mode of operation, the model P-102, 1000 A probe, must not be used to measure any current which has an ampere (rms)•frequency product greater than 1200 A•kHz.

Current spikes or pulses should be converted to an ampere•frequency rating to determine whether or not they fall within these safe limits of operation.

The P-100, 10 A probe, is not subject to the limitations defined above.

**SAFE LIMITS**

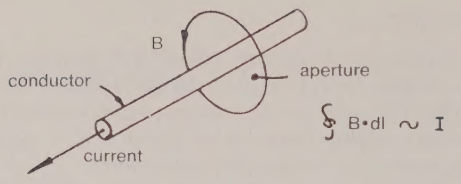
| PROBE | ac MODE | dc MODE |
|---|---|---|
| P-102 | 1200A•kHz | 1200A•kHz |
| P-101 | 750A•kHz | 1100A•kHz |

*Potential High Voltage Damage:* The magnetic fields associated with ac or transient currents generate a voltage in the 1776 probes. For waveshapes which exceed the specified safe limits, this voltage becomes high enough to overload the protective devices in the instrument and do extensive damage to the circuitry.

*Potential Thermal Damage:* If the measured current is greater than the ampere•frequency limits, the temperature of the core in the probe could rise above the designed thermal limit. This increase in temperature will adversely affect the sensing element in the probe. Depending on the circumstances, the damage incurred by the probe may be permanent.

## SECTION VI
## Theory of Operation

A magnetic field is associated with every current flow. The strength of the magnetic field is related to the magnitude of the current. Ampere's Law states that the line integral of magnetic field (this is an integral around a closed path) is proportional to the net current flow through the line aperture. The Bell Model 1776 Digital Current Meter operates on the principle of Ampere's Law.




The Model 1776 probe consists of a magnetic core and Hall generator. The core serves to concentrate the magnetic field surrounding the unknown current. In addition, the core approximates the line integral of magnetic field. The Hall generator, in a gap in the core, senses this concentrated, integrated magnetic field and provides a voltage output which is proportional to the current flowing through the core aperture. This voltage is delivered to the circuitry of the 1776.

This signal is amplified and conditioned to provide the various features and outputs of the digital current meter. Conductors external to the current probe normally will not effect the reading. The Hall generator is a high quality semi-conductor manufactured by F.W. Bell. Hall generators operate on the basis of the Hall effect. This effect occurs when a current flows through a conductor in the presence of a magnetic field. A voltage will be developed that is proportional to the current magnitude multiplied by the external field magnitude. In this way a voltage proportional to magnetic field is derived.

## MAINTENANCE FOR MODEL 1776 CURRENT METER

### 1. INTRODUCTION

This section contains the necessary instructions and diagrams for maintaining the Model 1776 Digital Current Meter. In addition to the schematic diagram, a block diagram showing typical voltage levels is provided to aid in troubleshooting. Repair and adjustment of the instrument should be attempted in the field only where adequate test equipment and qualified personnel are available. Refer to the warranty page for the procedure to be followed should factory repair service be required. Caution: CMOS. Proper handling procedures must be used.

### 2. TEST EQUIPMENT

Voltmeter—Fluke 8000A or equivalent
Oscilloscope—Tektronix 503 or equivalent

### 3. COVER REMOVAL

Caution—Always disconnect the power cord from the power line when removing or replacing the cover. To remove the cover, remove the two screws on the rear and one screw from the front panel of the unit.

### 4. PERFORMANCE TEST

#### A. Preliminary

1. Make sure the power cord is properly connected and fully seated in the receptical.
2. Check the fuse for burn-out. Correct fuse size is ⅛ amp 3AG slow-blow for 110 Volt operation; 1/16 amp 3 AG slow-blow for 220 Volt operation.
3. Check the battery connections on the PC board and at the batteries.
4. Check for damage to the probe, cable, connector contacts, cores, etc.

#### B. Calibration Check

1. Plug the probe securely into the front panel.
2. Push the CAL button in; the meter should read near 1000.
3. Using the CAL control, a meter reading of 1000 should be obtainable with approximately 20 counts on each side of 1000.
4. Voltage at the output jacks should be 1 Volt dc for a full scale (1000) meter reading ±2 counts.

#### C. Zero Test

1. Release the CAL button and return to the dc mode of operation. Adjust the zero controls to obtain a zero meter reading.
2. A total range of approximately −700 to +700 counts typical should be obtainable.

#### D. Peak Read Test

1. With the ac/dc switch out (instrument in the dc mode), use the zero controls to adjust a plus (+) 010 counts on the meter.
2. Push in the Peak hold button and reset the Peak Detector Circuit by temporarily depressing the Peak Reset Button. The meter should then read 010 counts ± one digit.
3. While holding the Peak Reset Button in, the meter should read 000 ± one count.
4. Release the Peak Reset and Hold Buttons (return to the dc mode of operation) and use the Zero Controls to set plus (+) 700 counts on the meter.
5. Push in the Peak Hold Button and reset the Peak Detector by temporarily depressing the Peak Reset Button. The meter should then read 700 ± one count.

### 5. ADJUSTMENT AND ALIGNMENT PROCEDURE

#### A. Digital Voltmeter (DVM) Adjustment

1. Disconnect probe from the 1776 Digital Current Meter.
2. Connect an external voltmeter to the output jacks on the front panel of the 1776.
3. Using the Zero Controls on the front panel of the 1776, obtain a zero reading on the external voltmeter.
4. Depress ac/dc switch. The digital voltmeter display should read zero; if not, adjust the ac null pot (R227) and then release ac/dc switch.
5. Temporarily connect pin P-114 to terminal P-20S of the meter board (bottom terminal) with a clip lead.

6. In the dc mode, adjust front panel Zero Controls R226 for a reading of 700 on the 1776's digital voltmeter display.
7. Depress ac/dc switch and adjust ac CAL control for a reading of 778 on the 1776's digital voltmeter display.
8. Remove the clip lead from pin P-114 and terminal P-20S of the meter board.
9. Re-zero the 1776's digital voltmeter display using the front panel controls.
10. Connect a probe to the 1776.
11. Depress the CAL button and use the CAL control to obtain a reading of 1.000 volts on external voltmeter.
12. Adjust dc CAL control to obtain a reading of 1.000 on the 1776's digital voltmeter display.

**B. Peak and Hold Calibration**

1. In the dc mode of operation, zero the 1776 instrument.
2. Depress the Hold Button.
3. While holding in the Reset Button, adjust R137 (internal zero adjustment) for a flashing plus sign (+) and a reading of 000 on the 1776's digital voltmeter display.
4. Release the Reset and Hold Buttons. In the dc mode, use the zero controls to set a reading of +010 on the 1776's digital voltmeter display.
5. Depress the Peak Hold Button. Push in and release the Peak Reset Button and adjust R138 (low level Peak CAL) for a reading of +009.
6. Release the Peak Hold Button. In the dc mode, use the zero controls to set a positive (+) 700 on the 1776's display.
7. Depress the Peak Hold Button. Push and release the Peak Reset Button and adjust R136 (high level Peak CAL) for a reading of 700 one count.
8. Release the Peak Hold Button.

Note: Low and high CAL adjustment (steps 5 and 7) must be approached from a lower level than the desired setting.

**C. Amplifier Adjustments**

1. Disconnect the probe; disconnect the blue/black and green/black leads from terminals P-128 and P-125.
2. Connect terminals P-103 and P-104 to each other.
3. Connect a 100 ohm ±20% resistor across pins P-101 and P-107.
4. Connect a 100 ohm ±20% resistor across pins P-101 and P-102.
5. Connect the ground lead of an external voltmeter to pin P-101 and the input to pin P-118.
6. Using a clip lead, connect the two shorted terminals P-103 and P-104 to pin P-101. Adjust R106 (offset null) for a reading of 0.000 Volt ±0.5 millivolt on the external voltmeter.
7. Remove the lead connected to pin P-101 in step 6 and connect it to pin P-102. Adjust R105 (Common Mode Rejection) for a reading of 0.000 Volts ±1 millivolt on the external voltmeter.
8. Remove the two 100 ohm resistors, clip lead, and short. Re-connect the blue/black lead to pin P-128 and the green/black lead to pin P-125 and check the operation of the 1776's zero controls.

## 1776 PARTS LIST
### Abbreviations

| | | | |
|---|---|---|---|
| Cer | Ceramic | MYL | Mylar |
| Comp | Composition | OP AMP | Operational Amplifier |
| DVM | Digital Volt Meter | Ω | ohm |
| Elect or ELE | Electrolytic | p | Pico or $10^{-12}$ |
| F | Farad | Reg | Voltage Regulator |
| FET | Field Effect Transistor | Seg | Segment |
| FOP | Factory selected for optimum performance | T | Tantalum |
| | | TG | Transmission Gate |
| IC | Integrated Circuit | μ | Micro or $10^{-6}$ |
| k | Kilo or $10^3$ | V | Working Volts |
| LED | Light Emitting Diode | Var | Variable |
| M | Meg or $10^6$ | W | Watt |
| MF | Metal Film | WW | Wire Wound |
| Mini DIP | 8 pin, dual in-line package | | |

## BASE PRINTED CIRCUIT BOARD

| Schematic Ref | Value | Specifications | | | F.W. Bell Item No. |
|---|---|---|---|---|---|
| R100 | 6.8 k Ω | 5% | 1/2 W | Comp | 313200 |
| R101 | 10 k Ω | 1% | 1/4 W | MF | 316350 |
| R102 | 10 k Ω | 1% | 1/4 W | MF | 316350 |
| R103 | 30.1 k Ω | 1% | 1/4 W | MF | 316350 |
| R104 | 29.4 k Ω | 1% | 1/4 W | MF | 316529 |
| R105 | 1 k Ω | | Cer | Var | 322044 |
| R106 | 20 k Ω | | Cer | Var | 322047 |
| R107 | 200 Ω | 1% | 1/4 W | MF | 315840 |
| R108 | 4.7 M Ω | 5% | 1/4 W | Comp | 312440 |
| R109 | 49.9 k Ω | 1% | 1/4 W | MF | 316579 |
| R110 | 4.87 k Ω | 0.1% | 1/4 W | MF | 315311 |
| R111 | 4.32Ω | 0.1% | 1/10 W | WW | 318375 |
| R113 | 121Ω-127Ω | 1% | 1/4 W | MF | FOP |
| R114 | 20 Ω | 0.1% | 1/2 W | Comp | 312600 |
| R115 | 5.11 k Ω | 0.1% | 1/4 W | MF | 315315 |
| R116 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R117 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R118 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R119 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R120 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R121 | 1 M Ω | 5% | 1/2 W | Comp | 313650 |
| R122 | 1 k Ω | 5% | 1/2 W | Comp | 313000 |
| R123 | 4.99 k Ω | 1% | 1/4 W | MF | 316240 |
| R124 | 10 k Ω | 1% | 1/4 W | MF | 316350 |
| R125 | 20 Ω | 5% | 1/2 W | Comp | 312600 |
| R126 | 20 Ω | 5% | 1/2 W | Comp | 312600 |
| R127 | 1.5 k Ω | 5% | 1/2 W | Comp | 313040 |
| R128 | 1 M Ω | 5% | 1/2 W | Comp | 313650 |
| R129 | 2 k Ω | 5% | 1/2 W | Comp | 313070 |
| R130 | 1 k Ω | 5% | 1/2 W | Comp | 313000 |
| R131 | 1 k Ω | 5% | 1/2 W | Comp | 313000 |
| R132 | 2 k Ω | 5% | 1/2 W | Comp | 313070 |
| R133 | 10 k Ω | 1% | 1/4 W | MF | 316350 |
| R134 | 5.11 k Ω | 1% | 1/4 W | MF | 316230 |
| R135 | 4.46 kΩ | 1% | 1/4 W | MF | 316230 |
| R136 | 1 k Ω | | Cer | Var | 322044 |
| R137 | 20 k Ω | | Cer | Var | 322047 |
| R138 | 2 k Ω | | Cer | Var | 322045 |
| R139 | 2.37 k Ω | 1% | 1/4 W | MF | 316171 |
| R140 | 200 Ω | 1% | 1/4 W | MF | 315840 |
| R141 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R142 | 100 k Ω | 1% | 1/4 W | MF | 313490 |
| R143 | 24.9 k Ω | 1% | 1/4 W | MF | 316515 |
| R144 | 24.9 k Ω | 1% | 1/4 W | MF | 316515 |
| R145 | 100 k Ω | 1% | 1/4 W | MF | 316620 |
| R146 | 130 k Ω | 5% | 1/2 W | Comp | 313510 |
| R147 | 270 k Ω | 5% | 1/2 W | Comp | 313580 |
| R148 | 10 k Ω | 1% | 1/4 W | MF | 316350 |
| R149 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R150 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R151 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R152 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R153 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R154 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R155 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R156 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R157 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R158 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R159 | 124 k Ω | 1% | 1/8 W | MF | 315128 |

| Schematic Ref | Value | Specifications | | | F.W. Bell Item No. |
|---|---|---|---|---|---|
| R160 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R161 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R162 | 124 k Ω | 1% | 1/8 W | MF | 315128 |
| R163 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R164 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R165 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R166 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R167 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R168 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R169 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R170 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R171 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R172 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R173 | 61.9 k Ω | 1% | 1/8 W | MF | 315140 |
| R174 | 8.2Ω | 5% | 2 W | WW | 319930 |
| R175 | 7.5Ω | 5% | 2 W | WW | 319920 |
| R176 | 3.3 Ω | 5% | 2 W | WW | 319845 |
| R177 | 620 Ω | 5% | 1/2 W | Comp | 312950 |
| R178 | 100 Ω | 5% | 1/2 W | Comp | 312770 |
| R179 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R180 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R181 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R182 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R183 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R184 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R185 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R186 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R187 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R188 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R189 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R190 | 10 k Ω | 5% | 1/2 W | Comp | 313240 |
| R191 | 1 k Ω | 5% | 1/2 W | Comp | 313000 |
| R192 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R193 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R194 | 100 k Ω | 5% | 1/2 W | Comp | 313490 |
| R195 | FOP | 5% | 1/2 W | Comp | FOP |
| R196 | 680 Ω | 5% | 1/2 W | Comp | 312960 |
| R197 | 47 k Ω | 5% | 1/2 W | Comp | 313400 |
| R198 | 24 k Ω | 5% | 1/2 W | Comp | 313330 |
| R199 | 47 k Ω | 5% | 1/2 W | Comp | 313400 |
| R101A | 3.3 Ω | 5% | 2 W | WW | 319845 |
| R102A | 10 Ω | 5% | 1/2 W | Comp | 312570 |
| R103A | 10 Ω | 5% | 1/2 W | Comp | 312570 |
| R104A | 22 M Ω | 5% | 1/2 W | Comp | 313670 |
| R105A | 470 k Ω | 5% | 1/2 W | Comp | 313610 |
| R106A | 10 M Ω | 5% | 1/2 W | Comp | 313680 |
| R107A | 240 Ω | 5% | 1/2 W | Comp | 312850 |
| R1 | 20 k Ω | 10 turn | | Var | 321680 |
| R2 | 250 k Ω | | | Var | 321245 |
| R3 | 5Ω | | | Var | 320965 |
| C101 | 2.2 μf @ 35 V | | | Tan | 325680 |
| C102 | 0.1 μf @ 20 V | | | Cer | 325230 |
| C103 | 0.0047 μf @ 200 V | | | Myl | 324450 |
| C104 | 180 pf @ 1000 V | | | Cer | 325400 |
| C105 | 0.1 μf @ 20 V | | | Cer | 325230 |
| C106 | 0.1 μf @ 20 V | | | Cer | 325230 |
| C107 | 0.1 μf @ 20 V | | | Cer | 325230 |
| C108 | 0.0033 μf @ 200 V | | | Myl | 324430 |
| C109 | 1 μf @ 35 V | | | Tan | 325670 |
| C110 | 0.001 μf @ 1000 V | | | Cer | 325510 |

| Schematic Ref | Value | | Specifications | F.W. Bell Item No. |
|---|---|---|---|---|
| C111 | 56 pf @ 1000 V | | Cer | 325330 |
| C112 | 330 pf @ 1000 V | | Cer | 325479 |
| C113 | 10 μf @ 16 V | | Elect | 323310 |
| C114 | 10 μf @ 16 V | | Elect | 323310 |
| C115 | 4700 μf @ 10 V | | Elect | 323030 |
| C116 | 350 μf @ 16 V | | Elect | 323380 |
| C117 | 350 μf @ 16 V | | Elect | 323380 |
| C118 | 350 μf @ 16 V | | Elect | 323380 |
| C119 | 5 μf (2-10 μf Caps) | NP | Elect | 323310 |
| C120 | 1 μf @ 35 V | | Tan | 325670 |
| C121 | .0047μf | | Myl | 324450 |
| C122 | .01 μf @ 200 V | | Myl | 325520 |
| C123 | 56 pf @ 1000 V | | Cer | 325330 |
| C124 | 10 pf @ 1000 V | | Cer | 325250 |
| C125 | .001 μf @ 1000 V | | Cer | 325510 |
| C126 | 10 pf @ 1000 V | | Cer | 325250 |
| C127 | 10 μpf @ 1000 V | | Cer | 325250 |
| C128 | .001 μf @ 1000 V | | Cer | 325510 |
| C129 | 100 pf @ 1000 V | | Cer | 325380 |
| C130 | 0.1 μf @ 20 V | | Cer | 325230 |
| C131 | .0047 μf @ 200 V | | Myl | 324450 |
| CR101 | 1N914 | | Diode | 328015 |
| CR102 | 1N456 | | Diode | 328000 |
| CR103 | 1N5231A (5.1V) | | Zener | 328450 |
| CR104 | 1N5231A (5.1V) | | Zener | 328450 |
| CR105 | 1N4003 | | Diode | 328090 |
| CR106 | 1N4003 | | Diode | 328090 |
| CR107 | 1N4003 | | Diode | 328090 |
| CR108 | 1N4003 | | Diode | 328090 |
| CR109 | 1N4003 | | Diode | 328090 |
| CR110 | 1N4003 | | Diode | 328090 |
| CR111 | 1N914 | | Diode | 328015 |
| CR112 | 1N914 | | Diode | 328015 |
| CR113 | 1N914 | | Diode | 328015 |
| CR114 | 1N914 | | Diode | 328015 |
| CR115 | 1N914 | | Diode | 328015 |
| CR116 | 1N914 | | Diode | 328015 |
| CR117 | 1N5343B (7.5 V) | | Zener | 328481 |
| CR118 | 1N5343B (7.5 V) | | Zener | 328481 |
| CR120 | 1N5231A (5.1 V) | | Zener | 328450 |
| Q101 | 2N3903 | | Transistor | 329030 |
| Q102 | 2N3903 | | Transistor | 329030 |
| Q103 | 2N3903 | | Transistor | 329030 |
| Q104 | T1573 | | FET | 329290 |
| Q105 | 2N5190 | | Transistor | 329190 |
| Q106 | 2N5190 | | Transistor | 329190 |
| Q107 | 2N3905 | | Transistor | 329040 |
| Q108 | 2N3903 | | Transistor | 329030 |
| Q109 | 2N3905 | | Transistor | 329040 |
| Q110 | 2N3903 | | Transistor | 329030 |
| Q111 | 2N3905 | | Transistor | 329040 |
| Q112 | 2N3903 | | Transistor | 329030 |
| Q113 | 2N5190 | | Transistor | 329190 |
| Q114 | 2N5193 | | Transistor | 329200 |
| IC101 | 741 | | Op Amp | 329985 |
| IC102 | 741 | | Op Amp | 329985 |
| IC103 | 741 | | Op Amp | 329985 |
| IC104 | 7805 | | Reg | 329984 |
| IC105 | 4001 (CMOS) | | Quad Nor | 330074 |
| IC106 | 709 | | Op Amp | 329950 |

| Schematic Ref | Value | Specifications | | F.W. Bell Item No. |
|---|---|---|---|---|
| IC107 | CA 3130 | | Op Amp | 330076 |
| IC108 | 311 | | Comparator | 329983 |
| IC109 | 741 | | Op Amp | 329985 |
| IC110 | 4040 (CMOS) | 12 Stage Ripple Counter | | 330073 |
| IC111 | 4011 | | Quad Nand | 330072 |
| IC112 | 78MO8 | | Reg | 329986 |
| IC113 | 79MO8 | | Reg | 329987 |
| IC114 | 4001 (CMOS) | | Quad Nor | 330074 |
| IC115 | 4016 (CMOS) | | Quad T G | 330075 |
| IC116 | 741 | | Op Amp | 329985 |
| IC117 | 741 | | Op Amp | 329985 |
| IC118 | 4001 | | Quad Nor | 330074 |
| L101 | Coil/Core | | Inductor | 326185/344379 |
| T101 | LA-1994 | | Transformer | 326035 |
| T102 | LB-1993/Core | | Transformer | 326187/344457 |
| I101 | #63 | | Lamp | 330481 |
| S101 | 6 Pole 5 Station | | Switch | 334399 |
| F101 | 1/8 A-110 V (SB) | | Fuse | 330700 |
| | 1/16A-220 V (SB) | | Fuse | 330680 |
| B1 | 5 volt | | Battery Pkg. | 335630 |
| J1 | | | Amp Connector | 331723 |
| | | For use in J1 (9) Pins | | 331351 |
| J2 | | | Connector, Power | ★ |
| P1 | | | Cord, Power | ★★ |

★ *331280 Used on Serial #192246 and Below*
*331282 Used on Serial #192247 and Above*

★★ *334770 Used on Serial #192246 and Below*
*334800 Used on Serial #192247 and Above*

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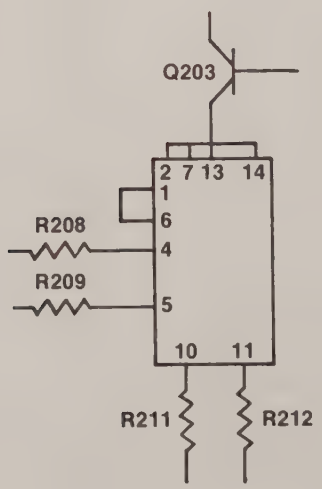
## 3-1/2 DIGIT PANEL METER

| Schematic Ref | Value | Specifications | | | F.W. Bell Item No. |
|---|---|---|---|---|---|
| R201 | 3.01 kΩ | 1% | 1/8W | MF | 315150 |
| R202 | 5.0 kΩ | 1% | 1/8W | MF | 315160 |
| R203 | 2 kΩ | | CER | VAR | 322045 |
| R204 | 10 kΩ | 5% | 1/4W | Comp | 312280 |
| R205 | 470 kΩ | 5% | 1/4W | Comp | 312339 |
| R206 | 300 kΩ | 5% | 1/4W | Comp | 312335 |
| R207 | 10 kΩ | 5% | 1/4W | Comp | 312280 |
| R208 | 150 Ω | 5% | 1/4W | Comp | 312087 |
| R209 | 4.7 Ω | 5% | 1/4W | Comp | 312080 |
| R210 | 10 kΩ | 5% | 1/4W | Comp | 312280 |
| R211 | 68 Ω | 5% | 1/4W | Comp | 312085 |
| R212 | 68 Ω | 5% | 1/4W | Comp | 312085 |
| R213 | 150 Ω | 5% | 1/4W | Comp | 312087 |
| R214 | 150 Ω | 5% | 1/4W | Comp | 312087 |
| R215 | 150 Ω | 5% | 1/4W | Comp | 312087 |
| R216 | 10 kΩ | 5% | 1/4W | Comp | 312280 |
| R217 | 49.9 kΩ | 1% | 1/8W | MF | 315127 |
| R218 | 24.9 kΩ | 1% | 1/8W | MF | 315126 |
| R219 | 24.9 kΩ | 1% | 1/8W | MF | 315126 |
| R220 | 49.9 kΩ | 1% | 1/8W | MF | 315127 |
| R221 | 49.9 kΩ | 1% | 1/8W | MF | 315127 |
| R222 | 24.9 kΩ | 1% | 1/8W | MF | 315126 |
| R224 | 10 kΩ | 1% | 1/8W | MF | 315121 |
| R225 | 49.9 kΩ | 1% | 1/8W | MF | 315127 |
| R226 | 10 kΩ | | CER | VAR | 322048 |

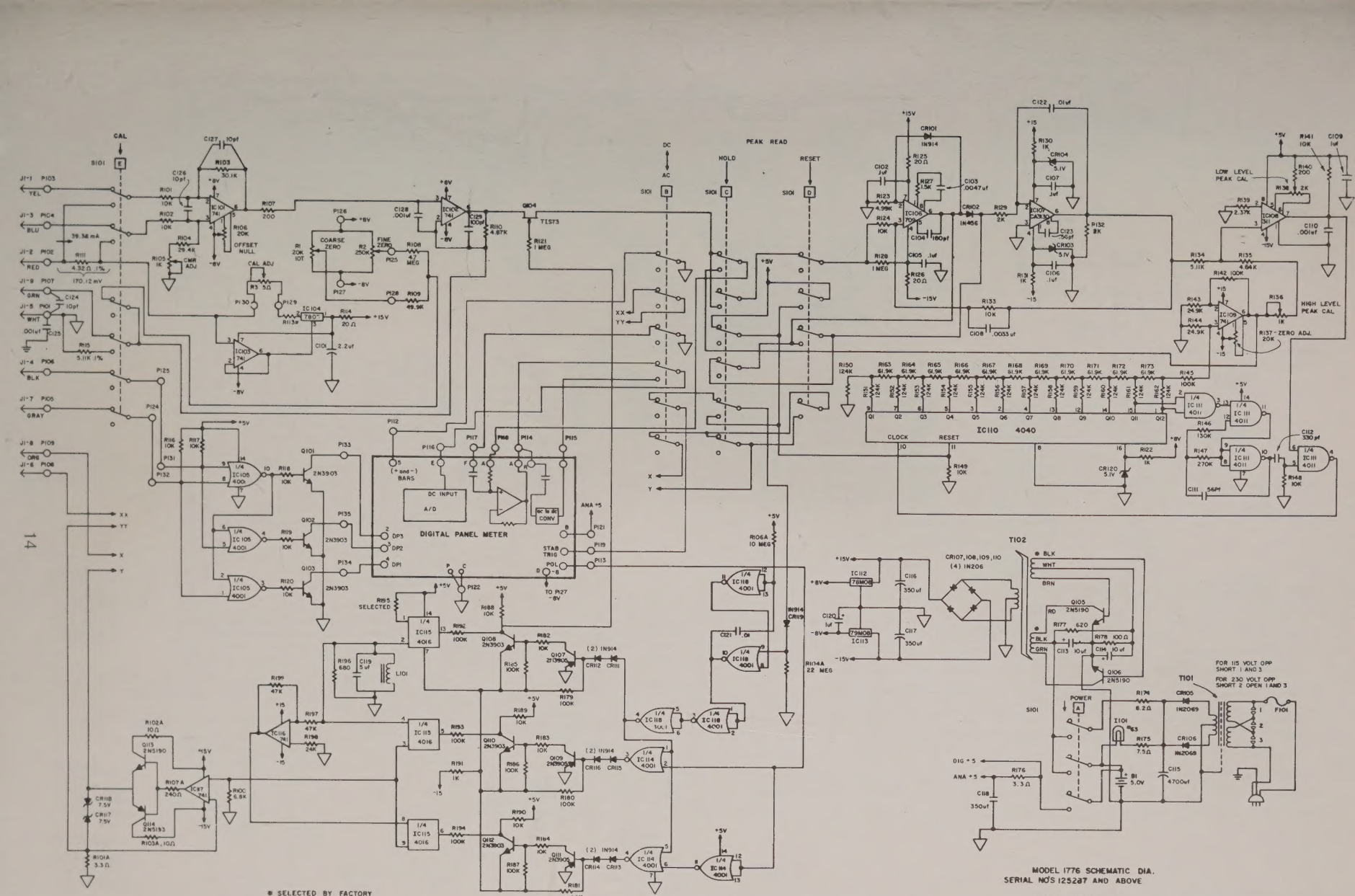
| Schematic Ref | Value | Specifications | | | F.W. Bell Item No. |
|---|---|---|---|---|---|
| | | | CER | VAR | |
| R227 | 20 kΩ | | | | 322047 |
| R228 | 10 kΩ | 1% | 1/8 W | MF | 315121 |
| R229 | 1.78 kΩ | 1% | 1/8 W | MF | 315091 |
| R230 | 10 kΩ | 5% | 1/4 W | Comp | 312280 |
| R231 | 10 kΩ | 5% | 1/8 W | Comp | 312280 |
| RN201 | 10 kΩ | 7-Resistor Network | | | 322705 |
| RN202 | 150 Ω | 7-Resistor Network | | | 322660 |
| C201 | .68 μf | TAN | | | 325690 |
| C202 | .68 μf | TAN | | | 325690 |
| C203 | 10 μf @ 16 V | Elect | | | 323310 |
| C204 | 10 μf @ 16 V | Elect | | | 323310 |
| C205 | .1 μf @ 400 V | Myl | | | 325171 |
| C206 | .1 μf @ 400 V | Myl | | | 325171 |
| C207 | 33 μf @ 16 V | NP Elect | | | 323390 |
| C208 | 3.3 μf | Elect | | | 323035 |
| CR201 | 1N914 | Diode | | | 328015 |
| CR202 | 1N914 | Diode | | | 328015 |
| Q201 | 2N3903 | Transistor | | | 329030 |
| Q202 | 2N3903 | Transistor | | | 329030 |
| Q203 | 2N3904 | Transistor | | | 329035 |
| Q204 | 2N3903 | Transistor | | | 329030 |
| Q205 | 2N3903 | Transistor | | | 329030 |
| Q206 | 2N3903 | Transistor | | | 329030 |
| Q207 | 2N3903 | Transistor | | | 329030 |
| Q208 | 2N3905 | Transistor | | | 329040 |
| IC-201 | 741 | OP AMP | | | 329985 |
| IC-202 | MC-1403 | 2.5 V REF | | | 329989 |
| IC-203 | MC-14433 | A/D | | | 330077 |
| IC-204 | MC-14558 | 7 Seg. Decode/Driver | | | 330070 |
| IC-205 | CD-3081 | Transistor Array | | | 329981 |
| IC-206 | 741 | OP AMP | | | 329985 |
| IC-207 | 741 | OP AMP | | | 329985 |
| IC-208 | CD-4011 | Quad Nand Gate | | | 330072 |
| LED-201 | hp5082-7650 | 7 Seg. LED | | | 330520 |
| LED-202 | hp5082-7650 | 7 Seg. LED | | | 330520 |
| LED-203 | hp5082-7650 | 7 Seg. LED | | | 330520 |
| LED-204 | hp5082-765 | +1 overflow | | | 330530*** |
| LED-205 | 5077B | LED | | | 329475 |

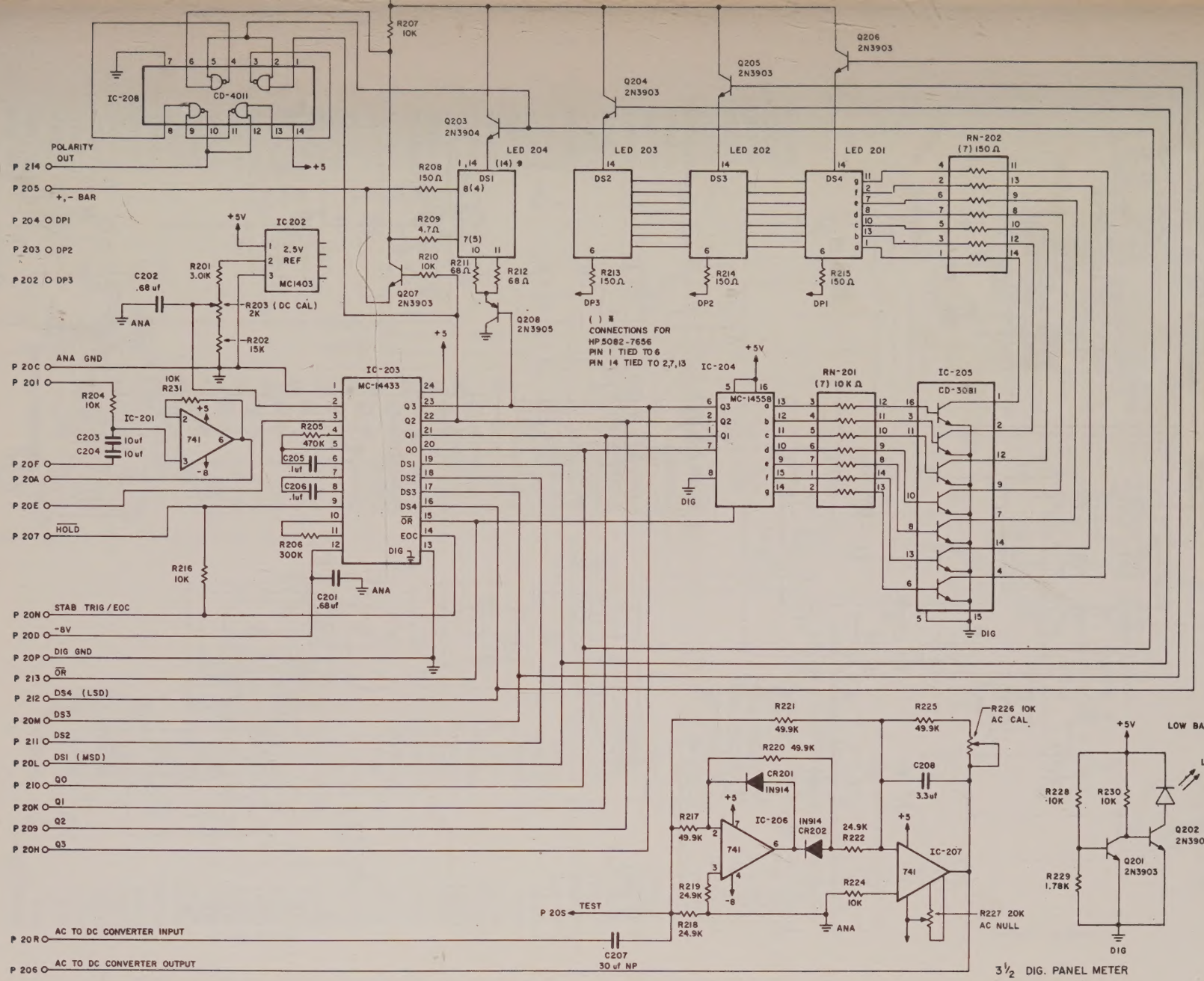
***330530 used in Serial #207667 and below
330535 used on Serial #207668 and above




**Note:** This connection applies only with serial numbers 207668 and above.

Connections for DSI HDSP 5082-7656 (30535) Refer UD-3316 REV. B. (Page 15)


CAL
DC
AC
PEAK READ
HOLD
RESET
LOW LEVEL PEAK CAL
HIGH LEVEL PEAK CAL
R137 - ZERO ADJ. 20K
IC110 4040
DIGITAL PANEL METER
DC INPUT
A/D
OFFSET NULL
CMR ADJ.
COARSE ZERO
FINE ZERO
CAL ADJ.
CLOCK
RESET
POWER
FOR 115 VOLT OPP SHORT 1 AND 3
FOR 230 VOLT OPP SHORT 2 OPEN 1 AND 3
* SELECTED BY FACTORY
MODEL 1776 SCHEMATIC DIA.
SERIAL NO'S 125287 AND ABOVE
UD-3500 REV. A


IC-208
CD-4011
POLARITY OUT
P 214
P 205
+,- BAR
P 204 O DPI
P 203 O DP2
P 202 O DP3
R207 10K
Q203 2N3904
Q204 2N3903
Q205 2N3903
Q206 2N3903
LED 204
LED 203
LED 202
LED 201
DS1
DS2
DS3
DS4
R208 150Ω
R209 4.7Ω
R210 10K
R211 68Ω
R212 68Ω
R213 150Ω
R214 150Ω
R215 150Ω
Q207 2N3903
Q208 2N3905
DP3
DP2
DP1
RN-202 (7) 150Ω
( ) = CONNECTIONS FOR HP5082-7656
PIN 1 TIED TO 6
PIN 14 TIED TO 2,7,13
IC 202
2.5V REF
MC1403
R201 3.01K
C202 .68 uf
R203 (DC CAL) 2K
R202 15K
ANA
ANA GND
P 20C
P 201
IC-203
MC-14433
IC-204
MC-14558
RN-201 (7) 10K Ω
IC-205
CD-3081
DIG
R204 10K
R231 10K
IC-201
741
C203 10uf
C204 10uf
R205 470K
C205 .1uf
C206 .1uf
R206 300K
C201 .68uf
R216 10K
P 20F
P 20A
P 20E
P 207
HOLD
P 20N
STAB TRIG / EOC
P 20D
-8V
P 20P
DIG GND
P 213
OR
P 212
DS4 (LSB)
P 20M
DS3
P 211
DS2
P 20L
DS1 (MSD)
P 210
Q0
P 20K
Q1
P 209
Q2
P 20H
Q3
R221 49.9K
R225 49.9K
R226 10K AC CAL
R220 49.9K
CR201 IN914
C208 3.3uf
R217 49.9K
IC-206
IN914 CR202
24.9K R222
IC-207
R219 24.9K
R224 10K
R218 24.9K
R227 20K AC NULL
P 20S
TEST
P 20R
AC TO DC CONVERTER INPUT
P 206
AC TO DC CONVERTER OUTPUT
C207 30 uf NP
LOW BATT CKT
LED 205
R228 10K
R230 10K
R229 1.78K
Q202 2N3903
Q201 2N3903
FOR 2.000 V FS
R201 = 3.01K
R202 = 15.0K
R205 = 470KΩ
FOR 200 mv FS
R201 = 17.4 KΩ
R202 = 0 Ω
R205 = 47 KΩ
3½ DIG. PANEL METER
DWG NO. UD-3316
REV B

# WARRANTY

F.W. BELL, INC. warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to replacing any defective parts thereof (excluding batteries). This warranty covers instruments which, within one year after delivery to the original purchaser, shall be returned with transportation charges prepaid by the original purchaser, and which upon examination shall disclose to our satisfaction to be defective. If it is determined that the defect has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost after submitting an estimate to the purchaser.

F.W. BELL, INC. reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of F.W. BELL, INC., and F.W. BELL, INC. neither assumes nor authorizes any other person to assume for them any other liability in connection with the sales of F.W. BELL, INC. instruments.

## DAMAGE IN SHIPMENT

The instrument should be examined and tested as soon as it is received. If it does not operate properly, or is damaged in any way, immediately file a claim with the carrier. The claim agent will provide report forms. A copy of the completed form should be forwarded to us. We will then make the necessary arrangements for repair or replacement. All correspondence concerning this instrument should include model and serial numbers.

## SHIPPING INSTRUCTIONS

Use the original shipping carton and inserts, if possible, or pack the instrument in a sturdy container and surround the entire instrument with two or three inches of shock-absorbing material.

Ship to:

**F.W. BELL, INC.**
Repair Department
6120 Hanging Moss Road
Orlando, FL 32807
Phone: 407-678-6900
TWX: 810-853-3115
Fax: 407-677-5765

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